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LaslonDef - Wrocław 2024

Photonic simulations using COMSOL

Hands on workshop

Part 2. Eigenfrequency analysis - photonic band structure

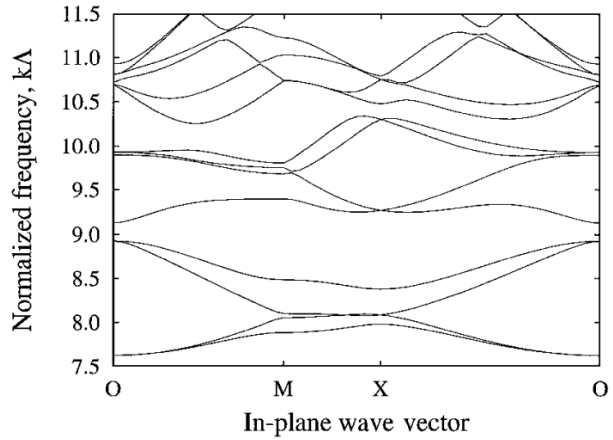

Fig. 1. Photonic band-structure diagram of a silica–air triangular photonic crystal with a 70% air-filling fraction.

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HR EXCELLENCE IN RESEARCH

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Photonic crystal fibers - introduction

Photonic crystal

- Optical medium with periodic variation of refractive index
- Period is of the order of wavelength

Photonic bandgap

- Complete photonic bandgap can arise – light from a certain spectral range cannot propagate in the photonic crystal

Photonic crystal fibers

- Photonic crrystal fibers can be viewed as a two-dimensional photonic crystal with a defect
- The defect forms core and the lattice forms cladding

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Calculating photonic band-structure

Eigenfrequency analysis

- What frequencies can propagate in the structure for a given wavevector?
- Due to periodicity wavevectors can be chosen from the first Brillouin zone only

Input

- Definition of a unit cel (geometry/material properties)
- Wavevectors - path along the border of irreducible Brillouin zone

Output

- Set of frequencies (and corresponding field distributions)

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Photonic band-structure - example

96 OPTICS LETTERS / Vol. 25, No. 2 / January 15, 2000

Analysis of air-guiding photonic bandgap fibers

Jes Broeng, Stig E. Barkou, Thomas Søndergaard, and Anders Bjarklev

Research Center Communications Optics Materials, Technical University of Denmark, Building 349, DK-2800 Lyngby, Denmark

Received September 21, 1999

https://opg.optica.org/ol/abstract.cfm?uri=ol-25-2-96

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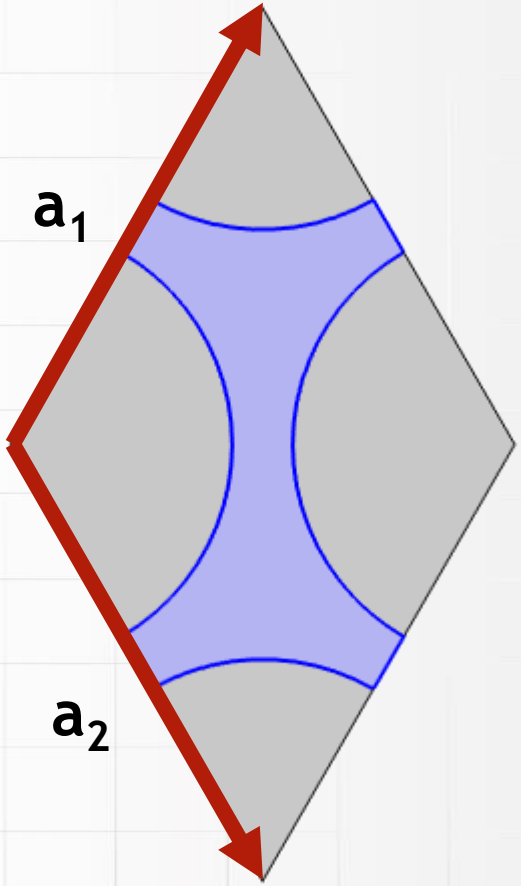
Photonic band-structure - example



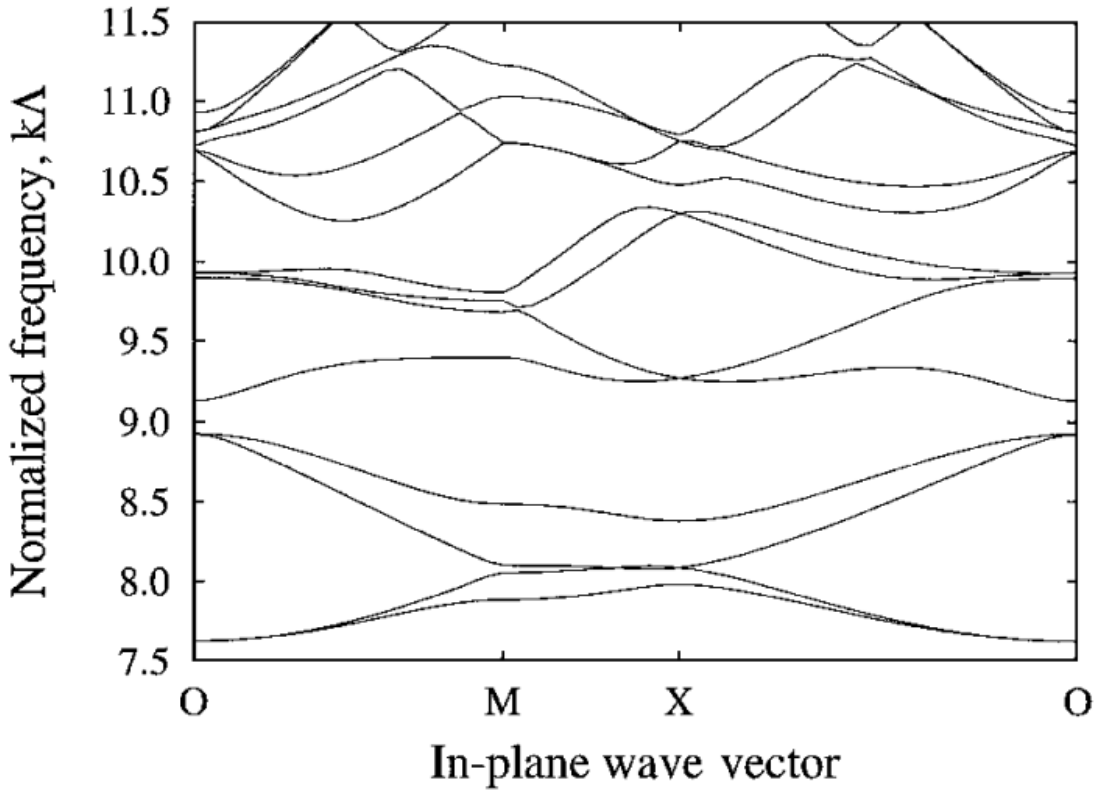


Fig. 1. Photonic band-structure diagram of a silica–air triangular photonic crystal with a 70% air-filling fraction.

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Photonic band-structure - example

$$\mathbf{a}_1 = \Lambda\left[\frac{1}{2}, \frac{\sqrt{3}}{2}, 0\right],$$

$$\mathbf{a}_2 = \Lambda\left[\frac{1}{2}, -\frac{\sqrt{3}}{2}, 0\right],$$

$$\mathbf{a}_3 = \Lambda\left[0, 0, 1\right].$$

$$\mathbf{b}_1 = 2\pi \frac{\mathbf{a}_2 \times \mathbf{a}_3}{V},$$

$$\mathbf{b}_2 = 2\pi \frac{\mathbf{a}_3 \times \mathbf{a}_1}{V},$$

$$\mathbf{b}_3 = 2\pi \frac{\mathbf{a}_1 \times \mathbf{a}_2}{V},$$

$$V = \mathbf{a}_1 \cdot \left(\mathbf{a}_2 \times \mathbf{a}_3\right).$$

$$\mathbf{b}_1 = \frac{2\pi}{\Lambda}\left[1, \frac{1}{\sqrt{3}}, 0\right],$$

$$\mathbf{b}_2 = \frac{2\pi}{\Lambda}\left[1, -\frac{1}{\sqrt{3}}, 0\right],$$

$$\mathbf{b}_3 = \frac{2\pi}{\Lambda}\left[0, 0, 1\right].$$

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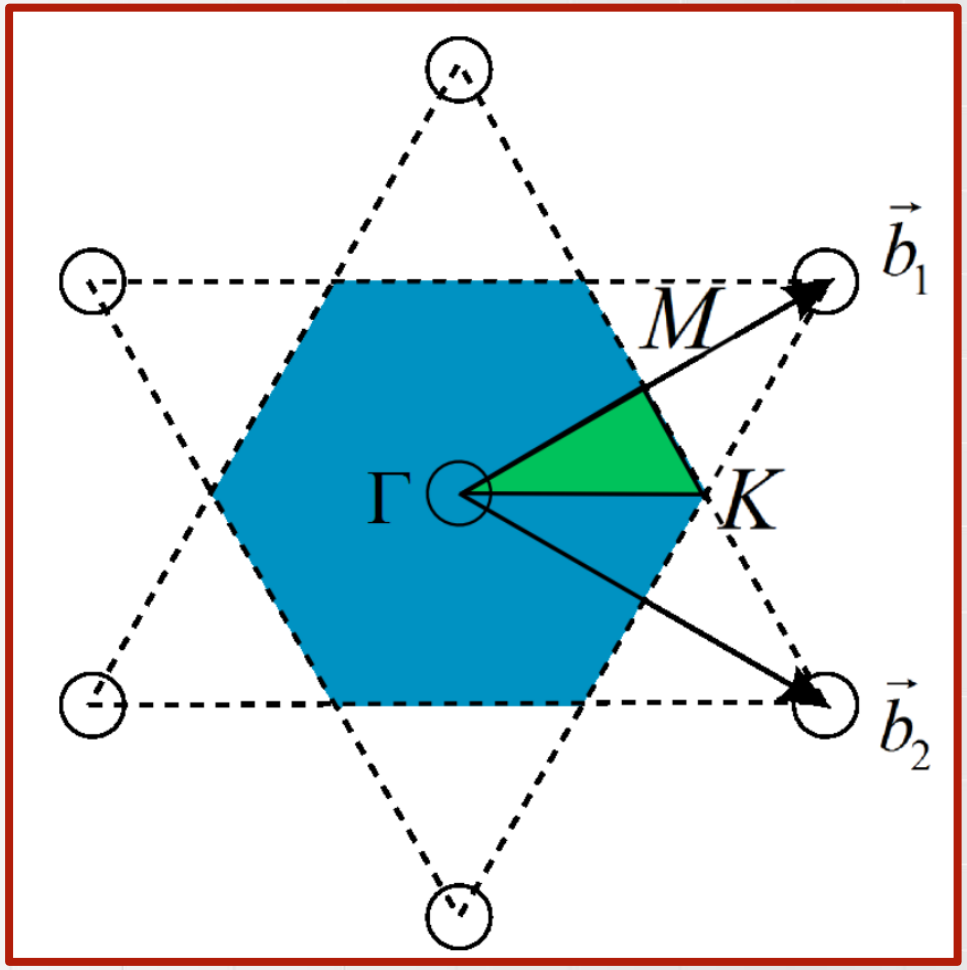
Photonic band-structure - example

$$\Gamma = 0 \cdot \mathbf{b}_1 + 0 \cdot \mathbf{b}_2,$$

$$M = \frac{1}{2} \cdot \mathbf{b}_1 + 0 \cdot \mathbf{b}_2,$$

$$K = \frac{1}{3} \cdot \mathbf{b}_1 + \frac{1}{3} \cdot \mathbf{b}_2.$$



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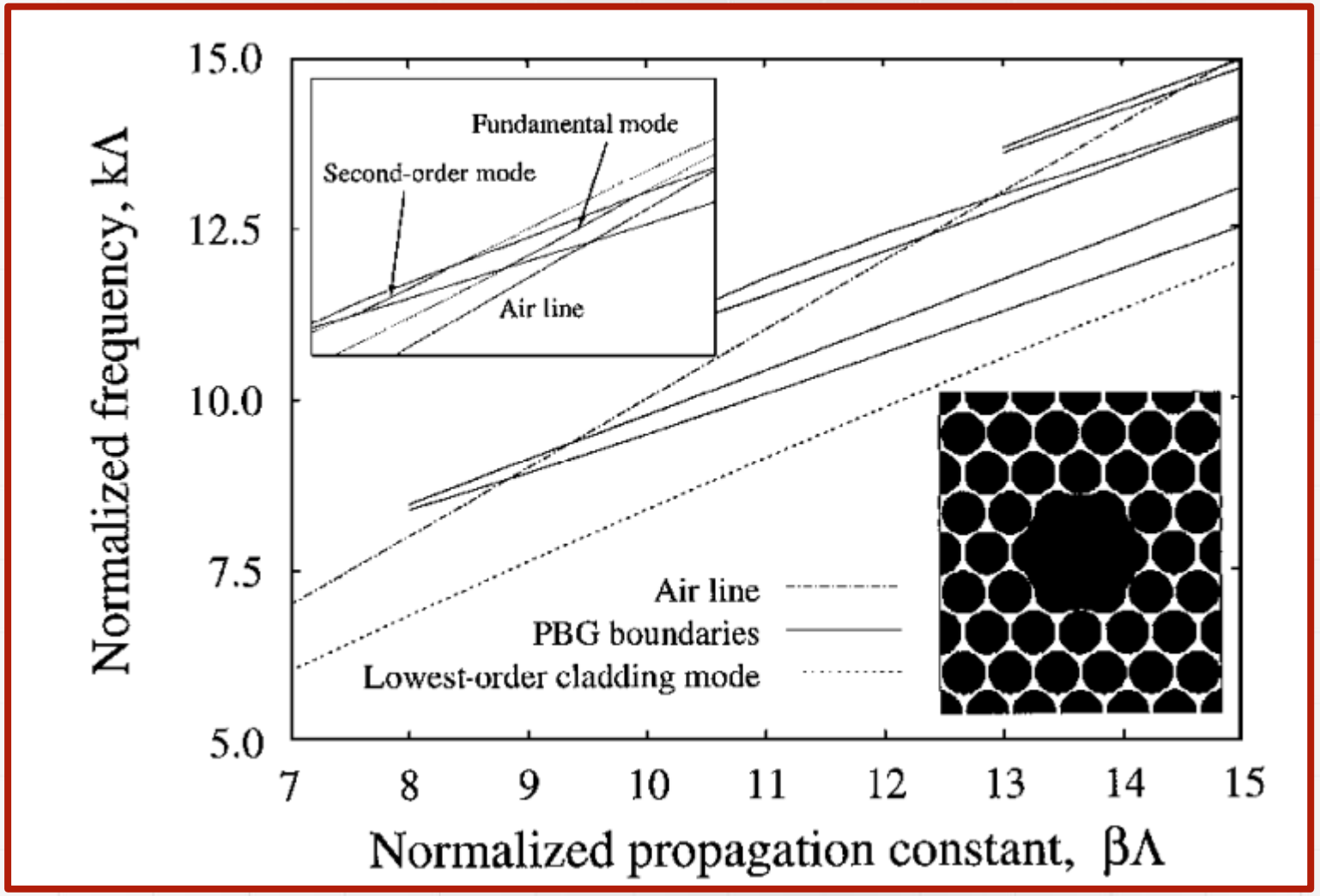
Photonic band-structure - example



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Photonic band-structure - example

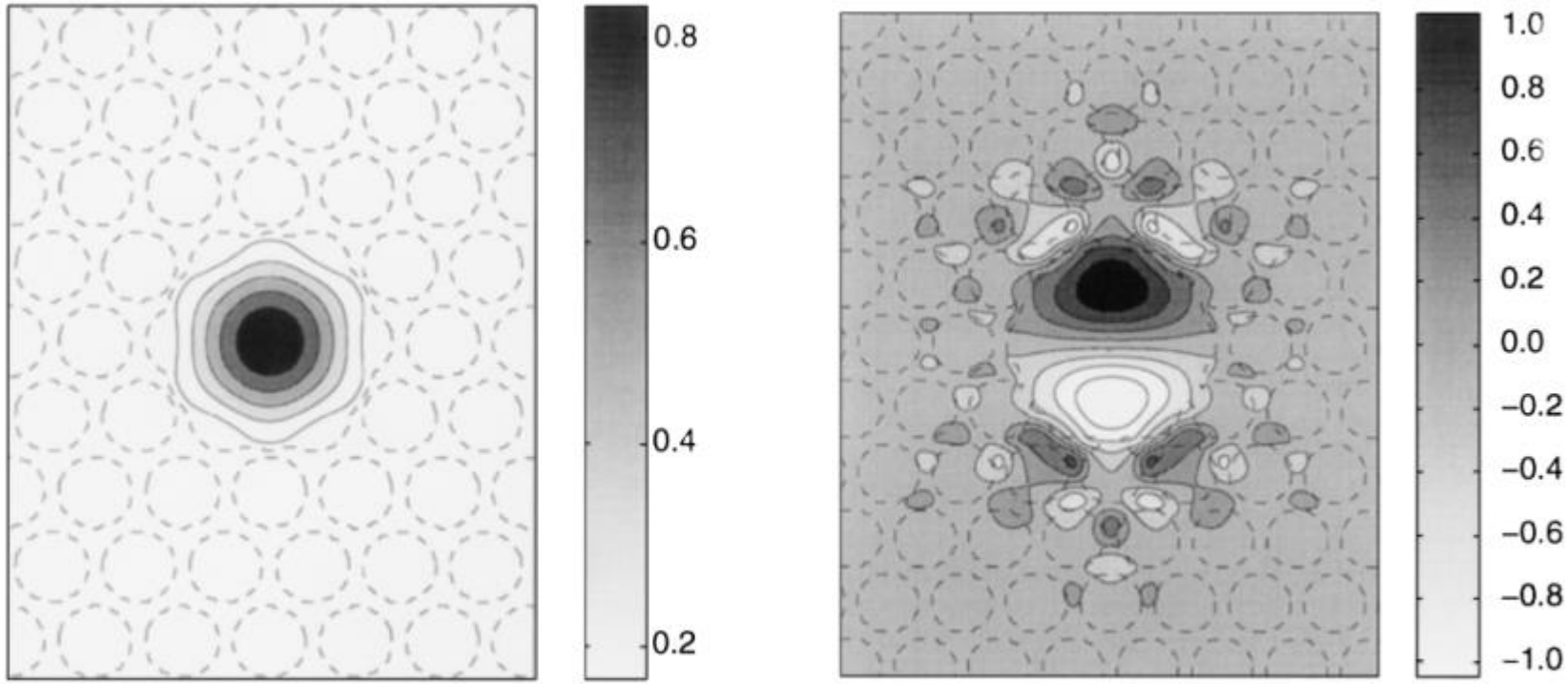

Fig. 3. Field distributions of (a) the fundamental air-guided mode and (b) the leaky second-order mode.

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Outline

Setting up the eigenfrequency analysis simulation (periodic boundary conditions)

Calculating photonic band gap structure using parametric sweep

Designing photonic crystal fiber